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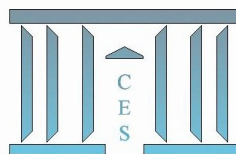
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**An Economic Model of the Stages
of Addictive Consumption**

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AN ECONOMIC MODEL OF THE STAGES OF ADDICTIVE CONSUMPTION

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The aim of this research is to build a model of addictive consumption by taking into account consumers' growing loss of self-control, as well as their lack of empathy for their future selves. Such model reveals that individuals follow a given consumption pattern composed of five stages, and thereby, that stable addictive consumption level does not exist outside of abstention. It permits to explain how consumers modify their environment in order to get rid of their addiction, and why some of them find it difficult to successfully abstain. The analysis of the model shows that they do not uniformly react to public policies according to the stage in which they are placed. I argue that an optimal policy should increase consumers' perceived losses of consuming without cutting too much their budget (as repeated price increases do). Moreover, it should be accompanied by more credible propositions of quitting strategies in order to prevent denial phenomenon and foster the decision to abstain. Furthermore, prices of such strategies should be low enough in order to favor a longer use of them and a quitting success.

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Keywords: addiction; cognitive biases; consumption choice; stages of change.

1. INTRODUCTION

Addiction refers to a specific consumption pattern that involves tolerance and reinforcement effects, as well as self-control issues, when the substance is not taken in a sufficient amount according to the (American Psychiatric Association, 2014). This paper focuses on addictions involving substance consumption such as cigarettes, alcohol or illegal drugs (by opposition to behavioral addictions as sport, video games or gambling). The specificity of substance use is to provide immediate and certain rewards, but also uncertain future losses which cover health, social and economic issues.

In economics, most of models explaining addiction derive from (Becker and Murphy, 1988) theory of rational addiction (TRA) where consumption of an addictive good induces the development of a stock of past consumptions, *i.e.* an addiction stock. The latter has a negative impact on the amount of utility derived from current consumption: in order to get the same amount of utility than previously, the individual has to increase his consumption of addictive good (phenomenon knew as tolerance effect). Moreover, this stock increases the marginal utility of the present addictive consumption: present consumption increases future consumption (reinforcement effect). In this framework, an individual decides to stop his addictive consumption due to an external event (Becker and Murphy, 1988; Gruber and Köszegi, 2001), or due to an endogenous parameter like a growing concern about the

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consequences of the addiction as the consumer ages (Goldbaum, 2000), or like his beliefs about the reversibility of risks (Carbone et al., 2005). However, the TRA ignores the phenomenon of loss of self-control over consumption: since it involves the consumption of amounts that do not correspond to the agent's decision, such a behavior is not considered as rational. Thus, in the TRA setting, when consumer makes the decision to abstain, he usually succeeds; leaving repeated quitting failures experimented by a part of individuals unexplained. Moreover, these models do not consider agent's capacity to modify their environment in order to facilitate abstention.

In order to explain those phenomena, the present paper proposes to build a model based on two existing frameworks. The first is (Suranovic et al., 1999) model which introduce increasing withdrawal costs that explain tolerance and reinforcement. However, the authors do not go so far as to include losses of self-control effect and thus do not explain quitting failures. The second comes from (Bernheim and Rangel, 2004) researches. Inspired from psychology, the authors introduced losses of self-control that the consumer can manage by resorting to quitting strategies. Nevertheless, the model puts aside the tolerance effect, by limiting the addictive consumption decision to a binary choice between consuming one single unit or abstention. By linking loss of self-control to withdrawal costs, the present paper permits to keep the advantages of those models, and to overcome their weaknesses. The consumption pattern that is found, shows many similarities with the stage of change path identified by psychologists (Norcross et al., 2011). In other words, individuals adopt a specific behavior according to the stage in which they are placed, thereby reacting differently to prevention policies that need to be adapted.

After having exposed the theoretical framework used in section 2, the model is built in section 3. The study of the individual consumption pattern in section 4 permits to identify a succession of addictive behaviors corresponding to the stages of change pattern. In section 5, the impact of different public policies is studied. and the section 6 gathers concluding remarks.

2. THEORETICAL FRAMEWORK

2.1. Related literature

In models deriving from the TAR, individual decides to consume an increasing amount of the addictive product as long as it provides him more utility than if he abstains, and when he decides to stop his consumption, he does not suffer of any withdrawal effects that could trigger losses of self-control. However, the latter is a criterion for addiction and substance abuse disorders pointed by the DSM-5² (American Psychiatric Association, 2014). Indeed, endowing the agent with a perfect rationality prevents him from such biases in his decisions. Thus, the TAR provides an analysis of addiction development, and of abstention decision conditions, but does not explain why some individuals do not manage to quit despite external shocks as price increases or health problems.

² DSM criteria referring to loss of self-control are "Taking the substance in larger amounts or for longer than they [consumers] meant to", "wanting to cut down or stop using the substance but not managing to" and "Cravings and urges to use the substance".

Withdrawal costs are at the core of Suranovic et al. (1999) model. By recognizing that the individuals do not have the infinite calculation capacities required to maximize their welfare on all their future periods of life, the authors assume that consumers have a bounded rationality in the sense of (Simon, 1972). In a static decision setting, and, with a finite number of periods of life, the agent maximizes a utility function which is additively composed of a benefit function, a loss function and an adjustment cost function. Benefit function refers to welfare that derives from the present consumptions of addictive goods. Loss function represents anticipated and actualized future (negative) effects of present consumption (*i.e.* the reduction of lifetime expectancy). Thus, it is increasing with the amount consumed and also as the last period of life becomes close. Adjustment cost function refers to quitting costs, *i.e.* withdrawal effects borne by consumer. At a given period of time, it decreases in an interval spreading between zero consumption and a given amount called the habitual level, which depends on past consumption. In other words, the higher the amount he decides to consume, the smaller the withdrawal costs. The latter disappear if consumption is higher than or equal to the habitual consumption level. However, consuming the habitual level raises the adjustment cost function in the next period by increasing the addiction stock. To resume, adjustment cost function is negatively linked to current addictive consumption level, and positively to addiction stock size. Depending on the adjustment cost function shape, which relies on personal characteristics, the agent stops progressively, or by “cold turkey”. In a third case, he tries to quit several times before succeeding, nevertheless the authors do not explain those aborted attempts.

For Suranovic et al. (1999), the sole impact of withdrawal costs is to decrease the consumer's utility for a given amount of addictive good. Consequently, if the utility maximization provides an amount of the addictive good corresponding to high adjustment cost, he is able to manage such withdrawal effects. Therefore, lack of self-control is still absent from this model, and quitting failure remain unexplained.

In this perspective, (Loewenstein, 2000) provides some interesting elements: he proposes a simple decision model that takes into account the emotions experienced by the individual when he makes a consumption decision. More precisely, some goods are associated to visceral effects which appear when consumption is too low and which “motivate” him to engage in a specific behavior. Thus, he can experiment two independent sets of preferences: the cold mode, in which he makes his decisions by maximizing his utility, and a hot mode in which his preferences are biased toward the good associated to visceral effects. The latter corresponds to a state of craving in which agent makes impulsive consumption decisions. This dual-process in decision making retains a particular attention in neuroeconomics and behavioral economics since it fits to behavioral data (Brocas and Carrillo, 2014). In addition of being activated alternatively, those modes are hermetic to each other: when the individual finds himself in one mode, he cannot take into account the parameters of the other mode even if he experienced this state many times. In other words, he overestimates his ability to resist to impulses (*i.e.* self-control), because of the difficulty of remembering short-term craving when making a decision in the cold mode (Thaler et al., 1997; Liu et al., 2014). This lack of empathy for future selves (Loewenstein and Schkade, 1999; Kahneman and Thaler, 2006) is commonly called the cold-to-hot empathy gap (Loewenstein, 2005) .

Bernheim and Rangel (2004) adapted Loewenstein's (2000) model to the context of addictive good consumption. At each period of time, a consumer placed in cold mode³ makes a choice between the consumption of one unit of the addictive good, and a total abstention. If he decides to abstain, there is a risk of entering into the hot mode and consuming the product. This risk is positively linked to his addiction stock. Thus, the contribution to Loewenstein work is to associate addictive goods to visceral effects (renamed “environmental cues”) that depend on past consumptions. The individual can manage those mode switches by attempting to control his own behavior. He is able to avoid environmental cues and diminish the probability of entering into the hot mode if he decides to abstain, and he can also decide to suppress the possibility of consuming the addictive good by entering in a rehabilitation cure.

Despite its qualities, this theoretical framework has two weaknesses. First, the decision to consume the addictive good only concerns one unit of it: the individual consume a constant amount of the addictive good during his whole career with a growing desire to consume it. Thus, only reinforcement effect and loss of self-control are taken into account whereas tolerance disappears from the model. In addition, the agent fully estimates his chances to enter into the hot mode and is able to manage it by maximizing his expected utility function (the sum of the probabilities of staying in the cold mode and of entering into the hot mode, associated to their respective utilities provided by the lifestyle chosen). Consequently, the model ignores the cold-to-hot empathy gap phenomenon.

2.2. The paper contribution

In this paper, a combination of Suranovic et al. (1999) and Bernheim and Rangel (2004) models is made by linking adjustment cost function to the hot mode activation. The latter does not only depend on the level of addiction to the product, it also relies on the amounts of addictive good chosen: the more the individual decides to consume, the smaller are the chances for the hot mode to activate. In addition, agent's decisions are influenced by the empathy gap: instead of maximizing his expected welfare (the sum of the probabilized utilities in each mode); he only maximizes the welfare of the mode in which he is placed. In other words, when he makes his decisions in the cold mode, he only takes into account withdrawal effects that derive from his past consumptions and that lowers his current welfare, but omits to consider their potential action on the activation of the hot mode. It virtually conduces to choose consumption levels that are too weak and leads to the hot mode triggering inducing a higher consumption than planned (a loss of self-control).

Under this configuration, addiction stock has a double impact on preferences variation through the raise of adjustment cost function. On one hand, it lowers welfare, leading to a preference variation in the long run. On the other hand, it induces a higher probability of entering into the hot mode for a given desired amount of the addictive good, which results in a preference variation for the rest of the time period.

Indeed, by entering into the hot mode, the agent consumes more of the addictive product and increases the level of addiction stock in next period. Thus, by losing self-control

³ Consumer always makes his consumptions plans in the cold mode, either because he stayed in the cold mode in the previous period, either because the hot mode consumption satisfied his impulses, so he returned to the cold mode.

in the present, the individual increases the chances of losing self-control in the future for a given amount of addictive good: self-control is worsened by the cold-to-hot empathy gap.

Successive losses of self-control and the increase of adjustment cost function that derives can entail a situation, called critical level, in which consuming the addictive good becomes less attractive than the initial abstention situation. But because of the rise of the addiction stock, he cannot just make the decision of abstaining in order to return to this virginal state. This provokes an activation of long run regrets since the agent would like to get the abstinent utility but due to his adjustment cost, he cannot.

Some emotions lead people to re-examine their preferences (Livet, 2007). Whereas an individual feeling disappointment will often explain the negative consequences of his decisions by destiny, the emotion of regret supposes that he admits that the choice he made was wrong (Petit, 2015). Thus, long run regrets lead the agent to look for strategies that could help to abstain from the addictive consumption. Those strategies are similar to those enumerated by Bernheim and Rangel (2004), and have similar results in terms of abstinence pattern than in Suranovic et al. (1999) work. Their goal is to lower withdrawal effects which makes easier to stay in the cold mode even if he reduces his consumption. Avoidance strategy (or lifestyle) consists in avoiding the environmental cues, whose presence arouses the desire to consume the addictive product by increasing the subjective value of the drug (Hayashi et al., 2013). These cues are for instance products that the individual considers complementary to addictive consumption (coffee, alcohol in case of smoking) or objects suggesting the consumption (ashtrays full of butts). Consumers are gradually sensitized to them through the consumption of the addictive product via the classical conditioning phenomenon (Lazev et al., 1999)⁴. Here, the cost of avoidance strategy is non-monetary but induces a decrease of welfare: the individual adopts a less attractive lifestyle than before. Indeed, weakening temptations permits gradual abstention, thereby he has to adopt avoidance during successive periods of time before completely abstaining. The second possible quitting strategy is the rehabilitation consisting in a voluntary remove of the possibility of consuming the addictive product. It leads to cold turkey abstention. Here, the individual also needs to resort to this strategy for a few time periods until the adjustment cost would have sufficiently diminished to permit efforts to be relaxed. Unlike avoidance, the price of rehabilitation is considered as monetary.

It is assumed that, as long as long run regrets are activated, agent remains careful about controlling his consumption: he bears in mind that returning to his old habits (by relaxing his efforts to abstain) will conduct his consumption pattern to the critical level which triggered the decision to abstain. Thus, when comparing an ordinary consumption (in the present paper, this kind of behavior is called exposition lifestyle) with the quitting strategies, he uses this critical level as a benchmark: he acts as if it corresponded to his present welfare and compares it to the actual welfares provided by the quitting strategies. In this perspective, what motivates former smokers not to smoke again is the comparison of actual abstention

⁴ The classical conditional theory consists in learning a new behavior by linking two stimuli together in order to produce a learned response. In case of smoking, environmental cues are linked to cigarette smoking. First, cigarettes are repeatedly consumed in given circumstances. As the smoker learn these associations, the usual environmental smoking setting transform to environmental cues that trigger the desire to consume when the smoker meet them. See Pavlov (1960).

welfare to the welfare that triggered the decision to abstain (they remember cough, and difficulties to breathe that cigarette consumption implied).

However, long run regrets can disappear after few period of time, leading the agent to compare anew the quitting strategies to the actual welfare provided by addictive consumption. In that case, as soon as adjustment cost would have decreased enough to make consumption of the addictive good anew more attractive than abstention, the individual will relax his efforts and progressively return to this former consumption. Sooner or later, he will once again be confronted to the critical utility that will activate long run regrets.

AS a result, an individual can fail to quit his consumption because of withdrawal effect are still present in avoidance lifestyle, but also because of the disappearance of long run regrets. The latter remain active from one period to another with a given probability. This probability depends on individual characteristics, and increases at each reactivation of long run regrets: the more the agent experiences the critical total utility, the more he will be perseverant in his attempts to remain abstinent: thus, people who relapse after a serious attempt (more than five days) have better chances to succeed in abstention during the next one (Caponnetto and Polosa, 2008).

A model correctly specified should describe a behavioral pattern actually observed in reality from the beginning of the consumption to total abstention. An interesting framework is based on Prochaska and his team thirty years' studies (Prochaska and DiClemente, 1983; DiClemente et al., 1991; Prochaska et al., 1992, 1994; Norcross et al., 2011): the stages of change. As it will be detailed in section 4, the present model fits very well with the pattern described by stages of change which permits a more complete interpretation of it.

2.3. Interpreting the results through a psychological perspective: the stages of change

Stages of change are composed of five typical stages that succeed each other in a defined order. This behavioral pattern concerns various problem behaviors (Prochaska et al., 1994) among which addictions (DiClemente et al., 2004).

First, the pre-contemplation stage concerns agents who are not aware of their addiction problem, and often express denial about the noxiousness of their consumption. It is most commonly observed when consumers have not yet developed an addiction for the product, and have stable consumption and welfare. Individuals in this stage report a refusal to modify their behavior in the long run.

In the following stage, contemplation, agents are beginning to consider a change in their behavior but remain ambivalent: on one hand, they recognize that their consumption has a negative impact on their lives, and on the other hand, they are afraid of changing. Usually, individual that report a desire to modify their behavior in the long run (one day), but who do not plan to do it within the six months, are associated to the contemplation stage.

Next stage is preparation, when behavior becomes problematic, and agents begin to lose control over their consumption. Although they plan behavior changes in the future without undertaking any concrete actions. Typically, literature considers that individuals who plan to change their addictive behavior within the six months are considered as being in the preparation stage.

In the action stage, agents make a firm and clear decision to change, and make commitments in order to overcome their problem. Individuals in the action stage have started

to modify their behavior (for instance, by diminishing their addictive good consumption), or who have modified their behavior for less than six months.

Finally, the maintenance stage concerns agents that abstain from smoking and continue to act in order to prevent relapses and to consolidate profits that they made during the action stage. Individuals that quitted their addictive consumption for more than six months, belong to this stage.

The sequence of stages of change can be summarized through the spiral of change, which refers to cycles of progressions and regression through the different stages. Each attempt increases the chances of overcoming the behavioral problem (that corresponds to the idea of the increase in regrets persistence at each of their apparition).

What is interesting with the present model, and the stages of change theory, is that every consumer can be identified with a specific stage, and thus, it is possible to predict how he will behave in the future. It permits to study the effects of different types of health policies according the stage in which the consumers are in order to identify which one is the more effective at which stage.

3. BUILDING THE MODEL

3.1. Individual's welfare

At time t , the consumer, chooses to allocate his resources between an addictive good s_t and a composite good y_t ⁵. It is assumed that he can neither save nor borrow, and that income (I) and prices (p_s, p_y) are constant through time. Moreover, it is supposed that satiation level is beyond his budget. The addiction good consumption induces the development of an addiction stock S_t that affects future welfare. As in the previous studies (Becker and Murphy, 1988; Carbone et al., 2005), a simple investment function is considered:

$$S_t = S_{t-1}(1 - \mu_s) + s_{t-1} \quad (1)^6$$

where μ_s is a fixed discount rate. Addiction stock is positively related to the habitual level of consumption s_t^h that represents the minimal amount of the addictive good that the individual needs in order not to suffer withdrawal effects. It is assumed that if the agent consumes an amount higher than or equal to this habitual level, then the addiction stock increases in the next period ($S_{t+1} > S_t$ and $s_{t+1}^h > s_t^h$ if $s_t \geq s_t^h$), whereas if the amount consumed is smaller, the addiction stock decreases.

As Suranovic et al. (1999), consumption at period t generates effects that are represented by a benefit function B_t , a loss function L_t , and an adjustment cost function C_t .

Benefit function refers to current benefits that the consumer derives from the consumption of (s_t, y_t) at t , and is assumed to be the same in the cold mode and in the hot mode. As in (Goldbaum, 2000), a quadratic function is used to model it. Since it has been assumed that income and prices are fixed, the parameters are rearranged by replacing y_t by $\frac{I}{p_y} - \frac{p_s}{p_y} s_t$ to obtain a function $B(s_t)$ (see *Appendix B.1*).

⁵ The composite good is composed of normal goods *i.e.* goods that do not generate any future benefits or losses.

⁶ This equation is equivalent to: $S_t = \sum_{i=1}^t (1 - \mu_s)^{t-i} s_{i-1}$.

Loss function represents the discounted value of the future negative effects of present consumption such as health effects, social disapproval, or job problems. It is assumed that, within a period of time, the loss function is linearly-increasing with s_t , and is null for $s_t = 0$. Exogenous shocks (as a public dissuasion campaign, personal health problems, a birth or a death in the family) are likely to modify $L(s_t)$ slope (see *section 6.2.*).

Adjustment cost function C_t represents the discomfort arising when the addictive good consumption is too weak (lower than the habitual level), *i.e.* withdrawal effects. Accordingly, C_t depends on the amount of addictive good consumed s_t , and on the habitual level of consumption s_t^h through the addiction, stock S_t . The function is positive or null in $s_t = 0$, and decreases with s_t in the interval $[0, s_t^h[$ to become zero for $s_t \geq s_t^h$:

$$\begin{cases} C(s_t, S_t) > 0 & \text{if } s_t < s_t^h \\ C(s_t, S_t) = 0 & \text{if } s_t \geq s_t^h \end{cases} \quad (2)$$

For simplicity of presentation, it is assumed that C_t slope remains constant whatever the amount of addiction stock S_t $\left(\frac{\partial C(s_t, S_t)}{\partial s_t} = \frac{\partial C(s_t, S_t')}{\partial s_t}\right)^7$.

In the present model, there are two representations of welfare. The first is utility function that represents agent's welfare in the absence of addiction development:

$$u(s_t) = B(s_t) - L(s_t) \quad (3a)$$

The second representation, total utility function, takes into account this phenomenon through the inclusion of C_t :

$$U(s_t, S_t) = B(s_t) - L(s_t) - C(s_t, S_t) \quad (3b)$$

Such a specification permits the consumer to assess his opportunity cost of having entered into the addictive good consumption. To do so, he uses $u(0)$ as a benchmark that he compares to his actual welfare $U(s_t, S_t)$.

$B(s_t)$ is a bell-shaped curve (see *Appendix B.2.*), and the functions $L(s_t)$ and $C(s_t, S_t)$ are linear, thus u and U_t are also bell-shaped curves.

The contribution of the present model is to consider that if $C_t = 0$, then the consumer always remains in the cold mode, whereas if withdrawal effects appear (*i.e.* if $C_t > 0$), then a risk of entering into the hot mode arises (see *section 4.*). Consequently to (2), the following relationship between $U_t(s_t, S_t)$ and $u_t(s_t)$ is derived:

$$\begin{cases} U_t(s_t, S_t) < u(s_t) & \forall s_t < s_t^h \\ U_t(s_t, S_t) = u(s_t) & \forall s_t \geq s_t^h \end{cases} \quad (4)$$

Thus, the higher C_t at a given level of s_t , the lower U_t will be (tolerance effect), and the more the agent will consume in order to remain as closer as he can on u function (reinforcement effect). Thus, adjustment cost function takes into account both of the addiction aspects defined by (Becker and Murphy, 1988).

⁷ It is assumed that the absolute value of the adjustment cost function slope depends on the consumer's profile (an exogenous parameter that contains personal sensitivity to environmental cues). If it is small, a given reduction in the addictive good consumption will have a small impact on his welfare (it will not hurt so much the consumer), referring to a weak addiction. At the opposite, a higher absolute slope refers to an individual that may develop strong addiction: a small decrease in consumption generates huge withdrawal effects.

3.2. Consumption choice

Each time period is composed of two phases: in the first one, the agent in the cold mode plans his consumption by maximizing his total utility:

$$\max U_t(s_t, S_t) \quad (5a)$$

Entering into the hot mode occurs with the probability θ_{C_t} , which positively depends on the level of withdrawal effects at the consumption level planned in the first phase. Thus, θ_{C_t} increases with S_t and decreases with s_t . Moreover when $C_t(s_t, S_t) = 0$, then $\theta_{C_t} = 0$. If the agent were perfectly rational, he would maximize his expected total utility⁸, however, due to the Cold-to-Hot Empathy gap, when in the cold mode, he does not take into account his hot mode preferences and estimates θ_{C_t} to be null. Doing so, he only maximizes his total utility (5a) according his current preferences. Thus, cold-to-hot empathy gap induces an increase of the chances to enter into the hot mode.

In the second phase, he consumes either according to his plans if still in the cold mode, or by consuming more than planned if in the hot mode. Indeed, in the hot mode, his preferences are biased toward the urge of minimizing withdrawal effects. His addictive consumption level s_t^h , results from:

$$\begin{cases} \max U_t(s_t, S_t) \\ s.t. C(s_t, S_t) = 0 \end{cases} \quad (5b)$$

A hot mode triggering leads to an increase of adjustment cost function in next time period (through an increase of S_t and s_t^h), that negatively impacts the total utility function on the interval $[0, s_t^h]$. In other words, for a given level of addictive good consumed in t , if the agent enters into hot mode, it will be more difficult for him to stay in the cold mode in $t + 1$.

If he attains the critical level $U^c(s_t, S_t^c) < u(0)$, that is to say, if the maximization of his total utility function provides him a lower satisfaction than if he never started to consume the addictive product, then he suffers long run regrets: he would like to get rid of his addictive consumption but he cannot since if he tries to lower his consumption, he will almost automatically enter into the hot mode due to high θ_{C_t} . As for consequences, he looks for a strategy that will help him to return to his initial utility level $u(0)$, by acting on C_t function.

4. THE MODEL WORKING

Since income and prices are assumed to be constant over time, then B_t , L_t and thus u_t have always a fixed value for a given amount of addictive good. However, C_t and thus U_t vary from one period to another for a given amount of addictive good, depending on S_t variations. As defined in *Section 3.1.*, C_t has a fixed slope over time. These assumptions allow a pattern of addictive behaviors to be identified, and which is composed of five distinct stages.

4.1. Precontemplation stage: a misperception of the addiction development (see Fig.1.A.)

Proposition1: U_t admits a constant maximum in $s^* > s_t^h$, when $\frac{\partial u(s_t)}{\partial s_t} > 0$ in $s_t = s_t^h$.

⁸ $E(U_t(s_t, S_t)) = (1 - \theta_{C_t})U_t(s_t, S_t) + \theta_{C_t}U_t(s_t^h, S_t)$, where $U_t(s_t, S_t)$ corresponds to the total utility when the agent stays in the cold mode while $U_t(s_t^h, S_t)$ is the total utility received in the hot mode.

Proof: u_t admits a maximum at $s^* \left(\frac{\partial u(s^*)}{\partial s_t} = 0 \right)$. When $s^* > s_t^h$, $C(s^*, S_t) = 0$ (see (2)), thus $U(s^*, S_t) = u(s^*)$ (see (4)). The welfare provided here corresponds to the maximal welfare attainable in the absence of addiction effects. Moreover, $s^* > s_t^h \Rightarrow S_t < S_{t+1} \Rightarrow C(s_t, S_t) \leq C(s_{t+1}, S_{t+1})$ and $s_t^h < s_{t+1}^h$ whatever $s_t = s_{t+1}$. If $s^* > s_{t+1}^h \Rightarrow C(s^*, S_t) = 0 \Rightarrow U(s^*, S_{t+1}) = u(s^*)$. The amount consumed, and the associated welfare remains unchanged from t to $t + 1$.

When the individual enters into the consumption of an addictive product, his adjustment costs are negligible. As long as adjustment costs have not developed enough, he chooses to consume this fixed amount s^* which provides a constant welfare $U(s^*, S_t) = u(s^*)$. Moreover, since withdrawal effects are null at this consumption point, he always stays in the cold mode. His welfare is equivalent what he would get in the absence of addiction development. Thus, the agent has no reason to be aware of the existence of adjustment cost since he has never experienced them. There is also no reason to consider consumption as a problem or to consider oneself as dependent on the addictive product. Consequently, the model predicts a temporary stable consumption s^* as long as $\frac{\partial u(s_t)}{\partial s_t} > 0$ in $s_t = s_t^h$, i.e. as long as $s^* > s_t^h$. This stability is only temporary since the adjustment costs grow.

4.2. Contemplation stage: an increase in consumption (see Fig.1.B.)

Proposition 2: when $s^* < s_t^h$, U_t admits a maximum in s_t^h as long as $0 > \frac{\partial u(s_t^h)}{\partial s_t} > \frac{\partial C(s_t^h, S_t)}{\partial s_t}$.

Proof: $U(s_t, S_t) = u(s_t) - C(s_t, S_t) \Rightarrow \frac{\partial U(s_t, S_t)}{\partial s_t} = \frac{\partial u(s_t)}{\partial s_t} - \frac{\partial C(s_t, S_t)}{\partial s_t}$.

If $0 > \frac{\partial u(s_t^h)}{\partial s_t} > \frac{\partial C(s_t^h, S_t)}{\partial s_t}$ thus $\frac{\partial U(s_t, S_t)}{\partial s_t} > 0$ in $s_t < s_t^h$ and $\frac{\partial U(s_t, S_t)}{\partial s_t} < 0$ in $s_t \geq s_t^h$ (since $U_t = u_t$ for $s_t \geq s_t^h$ and $\frac{\partial u(s_t)}{\partial s_t} < 0$ for $s_t > s^*$). Thus U_t admits a maximum in s_t^h .

As long as marginal utility exceeds marginal costs (i.e. $\frac{\partial u(s_t)}{\partial s_t} > \frac{\partial C(s_t, S_t)}{\partial s_t} > 0$), $U(s_t, S_t)$ has a positive slope on $s_t \in [0; s_t^h]$ - even when $u(s_t)$ decreases on $[s^*; s_t^h]$ interval - and a negative slope for $s_t > s_t^h$ where $U(s_t, S_t) = u(s_t)$. Thus s_t^h is the optimal consumption point here, which is higher than in the first stage ($s^* < s_t^h$), and which is associated to a smaller welfare: $U(s_t^h, S_t) = u(s_t^h) < u(s^*)$. In addition, consuming s_t^h makes S_t and $C(s_t, S_t)$ increase in the next period and the optimal amount of the addictive good to become $s_t^h < s_{t+1}^h$ and $U(s_t^h, S_t) > U(s_{t+1}^h, S_{t+1})$.

The agent is aware of the development of a tolerance and reinforcement effect for the addictive good since his welfare decreases from one period to another, as his consumption increases. However, he is not ready to change his habits, and continues to consume s_t^h , providing him a higher welfare than if he had never started to consume the addictive product ($U(s_t^h, S_t) > u(0)$). He has not yet suffered withdrawal effects since his optimal consumption point corresponds to null adjustment cost. Thus, he does not experience the hot mode yet. During this stage, there is no stable consumption level: it increases until to the point $s_t^h = \tilde{s}$ where $\frac{\partial u(\tilde{s})}{\partial s_t} = \frac{\partial C(\tilde{s}, S_t)}{\partial s_t}$.

4.3. Preparation stage: losses of self-control (see Fig.1.C.)

Proposition 3: when $\tilde{s} < s_t^h$, then $U(s_t, S_t)$ admits a maximum in $s_t = \tilde{s}$, then the consumer is likely to experience the hot mode.

Proof: \tilde{s} represents a point such as:

- when $s_t^h \leq \tilde{s}$, $C(\tilde{s}, S_t) = 0$ thus $\frac{\partial u(\tilde{s})}{\partial s_t} < \frac{C(\tilde{s}, S_t)}{s_t} < 0$
- when $s_t^h > \tilde{s}$, $C(\tilde{s}, S_t) > 0$ thus $0 > \frac{\partial u(\tilde{s})}{\partial s_t} = \frac{C(\tilde{s}, S_t)}{s_t}$

Thus, for $\tilde{s} < s_t^h$, there is $\frac{\partial U(s_t, S_t)}{\partial s_t} > 0$ in $s_t < \tilde{s}$ and $\frac{\partial U(s_t, S_t)}{\partial s_t} < 0$ in $s_t > \tilde{s}$.

When $\tilde{s} < s_t^h$, then U_t increases in $s_t < \tilde{s}$ and decreases in $s_t > \tilde{s}$, (equaling the utility function for $s_t \geq s_t^h$). U_t admits a maximum in \tilde{s} , but this amount corresponds to positive adjustment cost ($C(\tilde{s}, S_t) > 0$ in $\tilde{s} < s_t^h$).

The agent actually consume \tilde{s} with the probability $(1 - \theta_{\tilde{c}_t})$ which implies $s_t^h > s_{t+1}^h \Rightarrow \theta_{\tilde{c}_t} > \theta_{\tilde{c}_{t+1}}$ and $U(\tilde{s}, S_t) > U(\tilde{s}, S_{t+1})$. Otherwise, he enters into the hot mode and consumes s_t^h implying $s_t^h < s_{t+1}^h \Rightarrow \theta_{\tilde{c}_t} < \theta_{\tilde{c}_{t+1}}$ and $U_t(\tilde{s}, S_t) < U_{t+1}(\tilde{s}, S_{t+1})$. Thus, the more he enters into hot mode, the more difficult it becomes for him to consume the desired amount \tilde{s} . By losing his self-control, he becomes aware of his dependence problem to the addictive good, but does not yet act to manage it.

According to his successes or failures to stay in the cold mode, the agent's consumption stabilizes around \tilde{s} or tends to rise, so this stage may last a long time. This behavior (choosing consumption of \tilde{s}) is maintained as long as his welfare remains higher than $u(0)$. Consequently, there is no stable level of consumption in this stage: the agent always plan to consume \tilde{s} , but depending on the hot mode triggering, his effective consumption is \tilde{s} or s_t^h (the latter vary at each period of time).

4.4. Action stage: attempts to get rid of the addictive consumption (see Fig.1.D.)

The agent attains a critical level $U^c(\tilde{s}, S_t) < u(0)$ when the amount of welfare he would have received if he had never started to consume the addictive product becomes greater than his actual total utility. This stage corresponds to the consumer's attempts to change addictive behavior in order to get rid of the addictive behavior by resorting to quitting strategies. Once the individual succeeds in abstaining, he passes to the next phase.

4.4.1. Spontaneous quitting or consumption reduction (exposition strategy E)

In the exposition lifestyle E , the individual faces usual environmental cues and does not bear extra costs. Progressively decrease the amount, or to go cold turkey would be irrational since the welfare associated, do not corresponds to total utility maximization. In order to abstain from his addiction, the agent needs to put in place a specific strategy.

4.4.2. Commitment: avoidance strategy A (see Appendix B.3)

When consuming the addictive product becomes less appealing than initial abstention, the agent also has the opportunity to lower the effects of environmental cues by adopting avoidance strategy A .

Proposition 4: if the agent chooses the avoidance strategy, his addictive consumption will decrease to a fixed level \tilde{s}^A , as his total utility will increase progressively until $\tilde{s}^A = s_t^h$.

Proof: the agent accepts to pay a non-monetary price $p_A > 0$ such as $B^A(s_t) = B(s_t) - p_A \Rightarrow u^A(s_t) = u(s_t) - p_A$. As compensation, the adjustment cost function becomes $(s_t, S_t)/m$, where $m > 1$ corresponds to the diminution of sensitivity to environmental cues.

Since $C(s_t, S_t)/m < C(s_t, S_t) \Rightarrow \theta_{C_t/m} < \theta_{C_t}$ for a given s_t and $\frac{\partial C(s_t, S_t)/m}{\partial s_t} > \frac{\partial C(s_t, S_t)}{\partial s_t} > 0$ but $\frac{\partial B^A(s_t)}{\partial s_t} = \frac{\partial B^E(s_t)}{\partial s_t} \Rightarrow \frac{\partial u^A(s_t)}{\partial s_t} = \frac{\partial u^E(s_t)}{\partial s_t} \forall s_t$. Thus $\tilde{s}^A < \tilde{s}$. As avoidance strategy diminishes the adjustment cost slope, it does not have any impact on s_t^h (which refers to a physical need).

Avoidance strategy is effective if the adjustment cost reduction is sufficiently large to obtain $C_t(\tilde{s}^A, S_t)/m < C_t(\tilde{s}^E, S_t)$, providing more chance of sticking to his consumption plans (see *Graph A.1.*). However, if m is too low, the diminution of adjustment cost slope can be insufficient to permit the agent to stay in the cold mode.

If long run regrets are activated, avoidance can be chosen if $\max U^A > \max U^c$. If the agent does not feel long run regrets, the strategy can be chosen as long as $\max U^A > \max U$.

The avoidance strategy takes place over a few periods. In a given period of time, if the individual remains in the cold mode, he consumes $\tilde{s}^A < s_t^h$, thus S_t and s_t^h decrease in the next period. The agent perseveres in the avoidance strategy until $\tilde{s}^A = s_t^h$. As he reaches this point, he is aware that if he continues to maximize $U_t^A(s_t, S_t)$, then the adjustment cost will increase again to reach $U_t^A(\tilde{s}^A, S_t) < u(0)$. This behavior can be explained by what (Elster, 2000) calls “Bunching”: the individual can bootstrap himself out of addiction by viewing each consumption of addictive good as a predictor of future consumptions. Thus, the choice is made between consuming the addictive product today and on latter occasions; and abstaining today and on latter occasions.

With long regrets still activated, he anticipates this situation and uses it as a benchmark when in compares consumption in the avoidance strategy with alternatives involving an abstention: $U_t(0, S_t)$, $U_t^A(0, S_t)$, $U_t^R(0, S_t)$. The agent then chooses the most advantageous. If he succeeds in abstaining, he passes into the next stage.

4.4.3. Pre-commitment: rehabilitation strategy R (see Appendix B.4)

Another option for the agent is to make a pre-commitment not to consume the addictive product during the period by deliberately degrading the utility of the alternatives in which he consumes the addictive good.

Proposition 5: if the agent chooses the rehabilitation strategy, his addictive consumption will immediately fall to zero, as his welfare will rise.

Proof: the agent pays a price $p_R > 0$ to make the adjustment cost null at $s_t = 0$ (it remains the same for the other values of s_t): $C(0, S_t) = 0 \Rightarrow \theta_{C_t^0}^R = 0$.

His budget becomes $I - p_R$, so the benefit function becomes $B^R(s_t)$, and total utility becomes discontinuous: it is equal to $B^R(s_t) - L(s_t)$ in $s_t = 0$ and to $B^R(s_t) - L(s_t) - C_t(s_t, S_t)$ for $s_t > 0$.

To be chosen, the decrease of utility in $s_t = 0$ (induced by the payment of the price p_R), must be low enough. Adopting rehabilitation strategy makes the consumer totally abstain (see *Graph A.2*) and directly enter into the next stage.

4.4.4 Choice between the different strategies

The choice between the strategies E, A , and R requires taking into account two parameters. First, the price: paying p_R or p_A , is equivalent to a decrease in utility, whatever the value of s_t . The more expensive the alternatives are, the more the total utility function will be reduced and thus its maximum. However p_A and p_R do not impact $u(s_t)$ in the same way: p_A refers to an indirect payment (and is directly subtracted from the utility function), and p_R to a direct one (that impacts the budget and then the utility function). The second parameter that the agent takes into account is the maximum total utility value achievable: the counterpart for the price paid must compensate the losses in utility.

It is also important to note that if the quitting strategies available do not provide the agent a higher utility than the critical one, then he is forced to adopt the exposition lifestyle as long as he does not find a more advantageous alternative: he waits for a diminution in the quitting strategies costs, or waits to have a welfare low enough – thus below the critical utility – to make those strategies attractive.

The price of rehabilitation p_R is uniform across the agents, whereas the cost of avoidance p_A and its effects m on the slope of adjustment cost function vary from an individual to another. Indeed some individuals face more environmental cues than others, especially when their peers have the same addictive habits. For instance, a smoker used to smoke cigarettes while on the coffee break with colleagues but who do not specifically enjoy the coffee break alone, will experience a small p_A of avoiding coffee breaks, but if the coffee break is an important moment of socialization in the agent's office, the cost p_A will be large. In both cases, m will be an exogenous parameter (willpower). If the avoidance costs are too high, or if m is too small, then a rehabilitation strategy seems to be a better alternative.

4.5. The last stage: maintaining efforts to stay abstinent

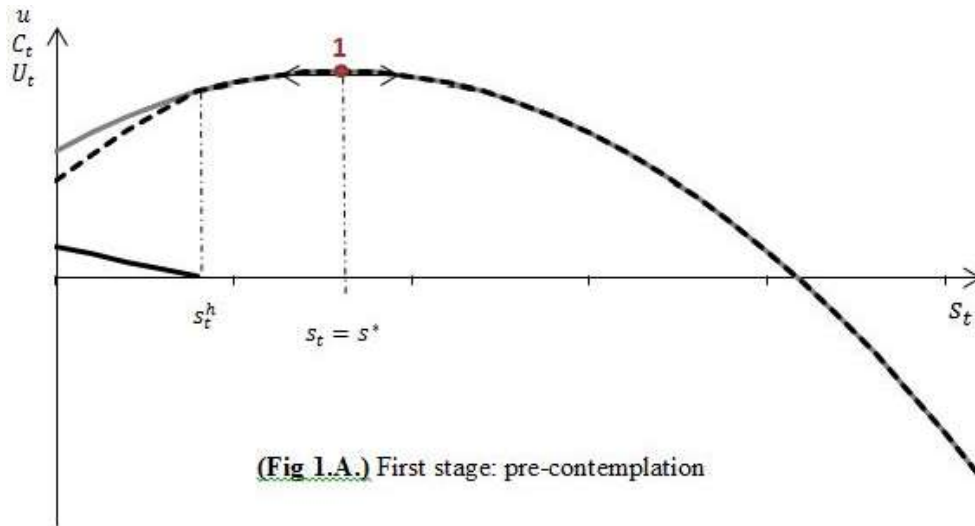
A successful abstention during one period does not mean that the individual has got rid of his consumption. Indeed he has to maintain his efforts in order to ensure that he will not relapse and return to his old habits.

The individual continues to compare the welfare provided in each of the three lifestyles for a null amount of addictive product consumed. Therefore, the persistence of long run regrets is still essential not to succumb to the temptation of getting a bigger but temporary welfare by consuming the addictive product again. This phase lasts as long as $U_t^A(0, S_t) > U_t^E(0, S_t)$ if he has chosen avoidance strategy, and as long as $U_t^R(0) > U_t^E(0, S_t)$, if he has chosen rehabilitation. This situation is brought to an end when $U_t^E(0, S_t)$ becomes the optimal choice, *i.e.* when the costs of quitting strategies (constant) overcompensate their effects, the agent relaxes his efforts.

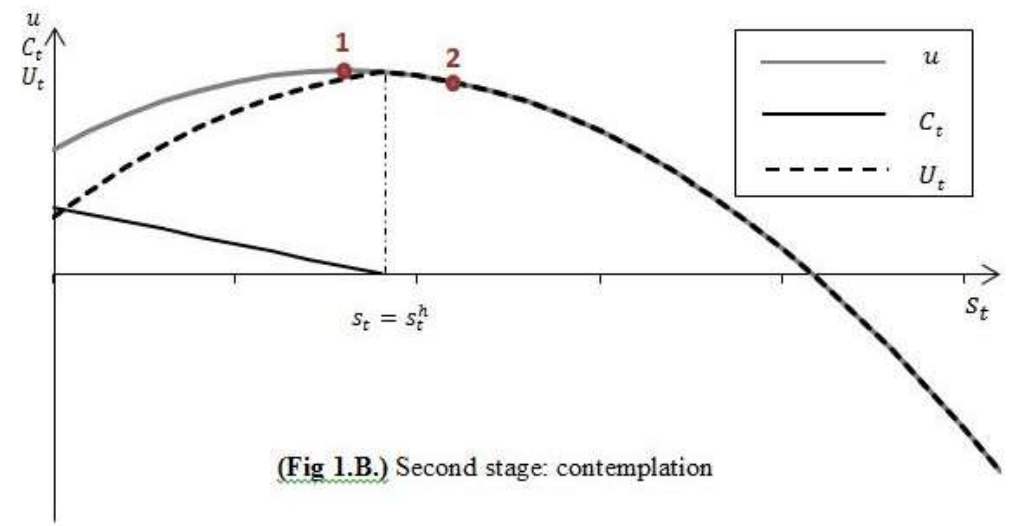
This abstention stage is the only one in which the individual tends to a stable level of addictive consumption: the more he remains in this stage, the higher the probability of succeeding in the abstention.

If the individual does not express any specific motivation to abstain from addictive consumption, and is just looking for utility maximization, the avoidance and the rehabilitation strategies will just help him to diminish his consumption until the exposition lifestyle again

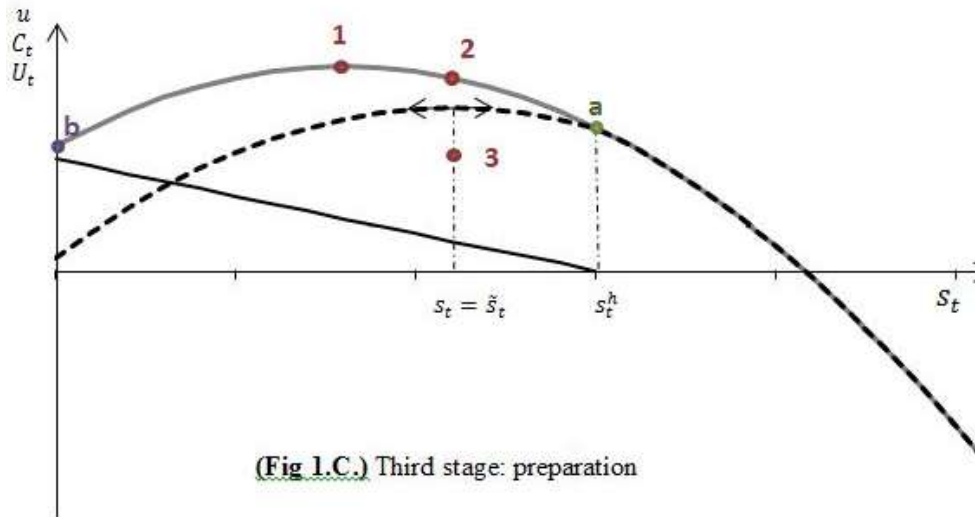
becomes more appealing than entering the spiral of changes. All things being equal, long run regrets are a driving force creating this specific motivation. But the costs borne by the individual when he chooses the avoidance strategy or rehabilitation are also important since they determine when the agent feels ready to relax his efforts.



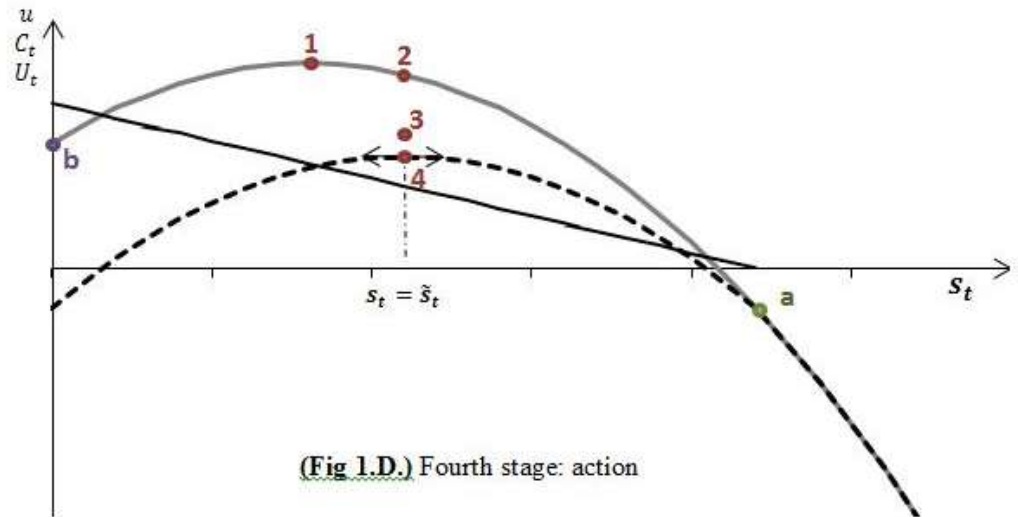
(Fig 1.A.) First stage: pre-contemplation



(Fig 1.B.) Second stage: contemplation



(Fig 1.C.) Third stage: preparation



(Fig 1.D.) Fourth stage: action

Fig.1. Utility function, Adjustment cost function and Total Utility function in first four stages. *Note:* In pre-contemplation stage, the individual consumes the amount s^* as long as s_t^h is smaller. The total utility received is constant. When $s_t^h = s^*$, he enters contemplation stage in which optimal consumption is s_t^h . During this stage, consumption increases and total utility decrease. The stage begins at the consumption point 1 and ends at the consumption point 2 when the marginal utility equals the marginal cost. In preparation stage, the maximization of total utility always provides the same optimal amount where which marginal utility equals marginal costs. It corresponds to positive adjustment cost. Moreover, if the agent enters into the hot mode, he consumes $s_t^h > \tilde{s}$ (point a). During this stage, the individual's consumption plans move between points 2 and 3 as the adjustment costs grow consequently to successive hot mode activations. When the total utility becomes lower than if the agent had never started smoking (the point b), he enters into action stage.

5. STUDYING AND INTERPRETING THE MODEL: IMPLICATIONS FOR PUBLIC POLICIES

5.1. An increase in the price of the addictive product (see *Appendix B.5*)

An increase in the price of the addictive good has a negative effect on benefit function and thus on utility function $u^s(s_t) < u(s_t)$ for $s_t > 0$. This negative effect grows with the amount of the addictive good s_t since the $u^s(s_t)$ slope decreases more than $u(s_t)$. Utility function is a bell-shaped curve, so it is deduced that the $u^s(s_t)$ curve reaches its maximum for a lower amount of the addictive good than before the price increase. Moreover that maximum corresponds to a lower amount of utility.

If the agent is in the pre-contemplation stage, then a moderate increase in the price of the addictive good will decrease its consumption until the new optimal point $s^{*s} > s_t^h$. If the price increase is substantial, and the new optimal point becomes $s^{*s} = s_t^h$, then the individual passes into the contemplation stage and consumes the amount s_t^h . If the agent is initially in the contemplation stage, a moderate increase in the addictive good's price has no effect on him if $\frac{\partial C(s_t, s_t)}{\partial s_t} > \frac{\partial u'(s_t)}{\partial s_t}$ in s_t^h point. If the increase is sufficiently large to give $\frac{\partial C(s_t, s_t)}{\partial s_t} < \frac{\partial u'(s_t)}{\partial s_t}$ in s_t^h point, then the individual passes in the preparation stage and consumes a smaller amount of the addictive good associated with a lower utility and positive adjustment cost. If initially in the preparation stage, his consumption will diminish and be associated with a smaller amount of total utility and trigger the hot mode with greater probability. Moreover, if he attains the critical level of utility that is smaller than an initial abstention utility $u(0)$, then the agent enters into the action stage. Therefore the action stage entrance occurs with lower adjustments costs than without any price increase. This makes quitting smoking easier.

There are similarities between those results and Suranovic et al. (1999) ones. For the authors, demand becomes unresponsive to price changes when quitting costs develop. Here, quitting costs have an effect on the demand responsiveness but the effect is not linear. Indeed, a given increase of the addictive good's price will have different immediate consequences depending on the stage in which the agent is. Moreover, reductions in the amounts of the addictive good consumed that are induced by the price increase in the pre-contemplation and preparation stages are only temporary because the individual continues to progress through the different stages of change (by increasing his consumption). Nevertheless this price increase accelerates the entrance into the action stage, which is made with smaller adjustment cost, making abstention easier. In other words, the visibility of an increase in the price of an addictive good is not immediate but should diminish the duration of the addictive consumption career *ceteris paribus*. Of course a drastic price increase would eliminate consumption, but its feasibility is controversial (it would be equivalent to a prohibition and induce a black market appearance).

5.2. An increase in the loss function (see *Appendix B.6.*)

A prevention campaign arousing fear about the negative health or social effects induced by the addictive product consumption is represented by an increase in the loss function slope.

Whatever the stage of change in which the individual is placed, an increase of the loss function does not generate a decrease in the utility (and total utility) function at the zero consumption point. Since it reduces the slope of the utility function, the latter becomes null earlier and equalizes the slope of the adjustment cost function for a smaller amount of addictive good. Moreover the utility function becomes smaller for $s_t > 0$, so the total utility function equalizes the abstaining-agent's utility for a lower s_t and a lower value of C_t . The optimal addictive consumption leads to smaller welfare. The stages succession is more rapid and corresponds to smaller adjustment cost and abstention attempts become more effective when the agent enters into the action stage.

The slope of the loss function may increase in case of a prevention policy which aims at increasing addicts' fears or promoting the benefits of a healthy life. It principally depends on the importance placed on the judgments of others, but concerns about health are also significant (an athlete will be more concerned by this parameter for instance). Even if the duration of these effects may generate debate, it is observed that the effects in terms of the addictive good's consumption are similar to those of an increase in the addictive good's price (but without a decrease in the budget). Thus, fear-invoking policies and healthy life propaganda seem to be credible alternatives to price increase that deserve to be studied specifically (especially in terms of persistence). Nevertheless, invoking fear has limits that are defined by the Extended Parallel Process Model (Witte, 1992): if the fear aroused is too intense, the agent will use cognitive strategies in order to diminish such fear, instead of looking for ways to protect himself from the dangers of addiction. In present model, it would be represented by a smaller increase in L slope than without cognitive strategies. One solution would be to propose credible strategies permitting control of such dangers: i.e. helping the agent to quit addictive consumption in order to enhance self-efficacy. In case of smoking, it has been shown that individuals with a large self-efficacy are more responsive to fear-appeal campaigns (Thompson et al., 2009). The agent accepts the danger presence which is represented by a higher increase in L slope. Another kind of prevention raising the loss function involves denormalization policies aimed at modifying norms: in feeling rejected by peers, an individual could then change behavior. This technique has led to debate, since stigmatization may lead agents who cannot easily modify their behavior to reinforce their dangerous behavior (Peretti-Watel, 2010). Therefore, it appears necessary to study the characteristics required to make a prevention campaign more efficient since a lasting increase of the loss function slope provides interesting results about the individual's behavior. Studies psychology should provide interesting avenues to be explored further.

As in Suranovic et al. (1999), it is considered here that a price increase and fear development have a positive effect on consumption reduction. However, it is not necessary immediate and durable. Moreover, the link between the concrete danger and fear is modulated by cognitive mechanisms.

5.3. Comparison between the effects of a price increase and an increase in the loss function (see *Appendix B.7.*)

Both prevention techniques have a speed-up effect on the successions of stages of change, and both permit entry into the action stage with lower adjustment cost, which facilitate the attempts of quitting. The difference between the two measures is the fact that a

price increase of an addictive good affects the agent's utility through the benefit function, whereas an increase of loss function directly decreases it without modifying its slope.

Although it is difficult to compare the effects of these two sources of variations (since fear and budget reduction do not belong to the same dimension), it is possible to compare the situations when they trigger the action stage, that is to say when $\max U^S(s_t, D_t) = \max U^L(s_t, D_t) = u(0)$ (for a given adjustment cost function). Since $\frac{\partial^2 u^S(s_t)}{\partial s_t^2} < \frac{\partial^2 u(s_t)}{\partial s_t^2} = \frac{\partial^2 u^L(s_t)}{\partial s_t^2}$ (see *Appendix B.4* and *B.6*), it can be deduced that the maximization of $U^S(s_t, D_t)$ leads to a smaller consumption of the addictive good than the maximization of $U^L(s_t, D_t)$, but corresponds to higher adjustment cost. If the rehabilitation strategy is more appealing, the utility obtained $u^{SR}(0)$ or $u^{LR}(0)$ is the same since $u(0) = u^S(0) = u^L(0)$. Thus, there is no difference in the effects of those prevention measures if the agent chooses rehabilitation strategy. However, if the avoidance strategy is chosen, the new optimal consumption point will correspond to a lower amount of the addictive good in the case of a price increase, and thus to higher adjustment cost. Consequently, the chances of succeeding in the attempt of reducing the addictive good consumption are smaller. Thus, when an increase in fear leads to the action stage, the individual that chooses the avoidance strategy stops smoking more slowly than in the case of a price increase, and is less subject to suffering from withdrawal effects, so the chances of success are greater.

This conclusion is only valid in the cases in which the two strategies trigger the action stage, but it does not take into account the costs induced to put them into place. Thus, a more detailed comparative analysis should be done.

5.5. Variation in the price of rehabilitation strategy (see *Appendix B.8.*)

The lower the price required to benefit from the rehabilitation strategy, the higher the utility to the zero addictive consumption point is. Moreover, a given decrease in rehabilitation price will have a stronger effect if the price is already low (marginal effect of a given price variation diminishes when the price increases). If the price decreases enough, the individual who previously opted for the avoidance strategy, will opt for the rehabilitation strategy which permits to enter immediately into the maintenance stage, without any risk of losing control.

It also has an important implication on the final success in abstention. Indeed, agent relaxes his efforts in the maintenance stage when abstention in the exposition lifestyle provides more welfare than abstention in the avoidance or rehabilitation strategy. thus, the lower the price for the alternative, the latter the agent will relax his efforts in maintenance stage, the smaller will be the adjustment cost, the greater will be the chances of success in abstention. For instance, if nicotine patches are expensive, the agent will certainly decide to stop using them earlier, maybe when the withdrawal effects have not diminished sufficiently, and so risk entering the hot mode.

6. CONCLUSIONS

This research paper models addictive behavior throughout the consumption “career”, by taking as a starting point two models that, taken alone, present a number of limits, but

combined, show interesting results. The association of Bernheim and Rangel (2004) losses of self-control to Suranovic et al. (1999) adjustment cost function (representing the withdrawal effects), as well as the inclusion of Loewenstein (2005) empathy gap phenomenon (the lack of empathy for the future selves), permits to find a behavioral pattern that matches with the stages of change theory (Norcross et al., 2011). It is an interesting result since each addictive product consumer can be placed in one of these five stages, and his future behavior and attitude toward his consumption are predictable.

In the model presented here, the role of the adjustment cost function is central since it explains the movements from one stage to another from the initiation to the final abstention. It also explains individual losses of self-control *i.e.* why he can find himself in situations in which he consumes more than he had planned to, and why he cannot abstain without resorting to quitting strategies (avoidance and rehabilitation). Long run regrets also play a key role in the model since their presence explain the individual's perseverance in maintaining new and healthier habits, after deciding to quit their addictive consumption, even once withdrawal effects have disappeared. The study of the model parameters permits to find that health policies, especially repeated price increases, do not have homogeneous effects on all agents according to the stage in which they are. However, they bring the agent closer to the next stage. Thereby, the action stage is triggered earlier, for smaller values of the adjustment cost function, making the attempts to abstain more effective.

The monetary cost of rehabilitation strategies has also to be discussed. Indeed, a decrease of it should have two effects: first, it incites the agent to choose the rehabilitation strategy instead of the avoidance, making his entrance into the maintenance stage certain. It also delays the when the agent relaxes his efforts to abstain from the addictive consumption, making the chances to relapse smaller.

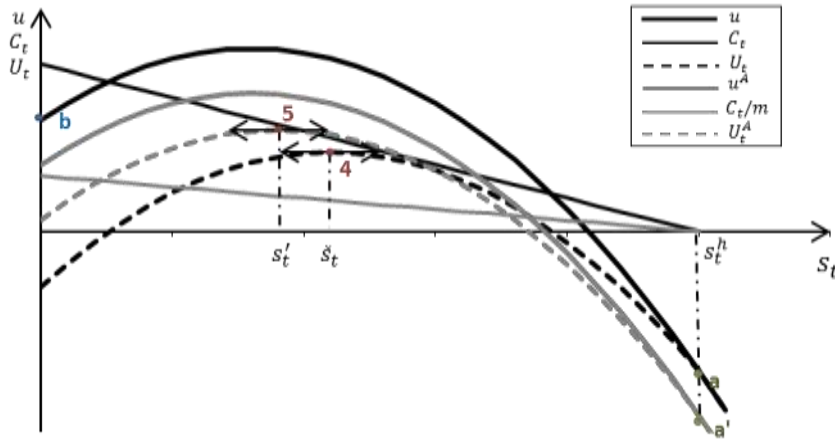
The last main result is that an increase in the loss function slope (via fear-appeal policies, the promotion of a healthy life or by changing social norms) has similar effects in terms of the addictive good consumption path than a price increase, but the former do not cut the agent's budget. It is an interesting result because taxation raises controversies about its inequitable nature toward modest consumers (Evans et al., 1999; Evans and Farrelly, 1998; Godefroy, 2004; Gruber and Mullainathan, 2005; O'Donoghue and Rabin, 2006).

Thus, it is necessary to discuss the possibilities of maintaining consumers' fear of the negative health effects of taking drugs especially in the smoking case. Indeed, a message that generates intensive fear can be rejected by cognitive rationalization (the agent tries to control the fear of danger instead of protecting himself from the danger), and has been shown in the literature (Gallopel, 2005; Witte, 1992). The extended parallel model (Gallopel, 2005; Witte, 1992) suggests that an effective fear campaign should be accompanied by the proposition of credible solutions providing support to an abstention from addictive consumption, that consumers would feel able to put in place reinforcing their self-efficacy. More precisely, self-efficacy is strengthened by the accessibility of quitting strategies (*i.e.* the cost of avoidance and rehabilitation strategies).

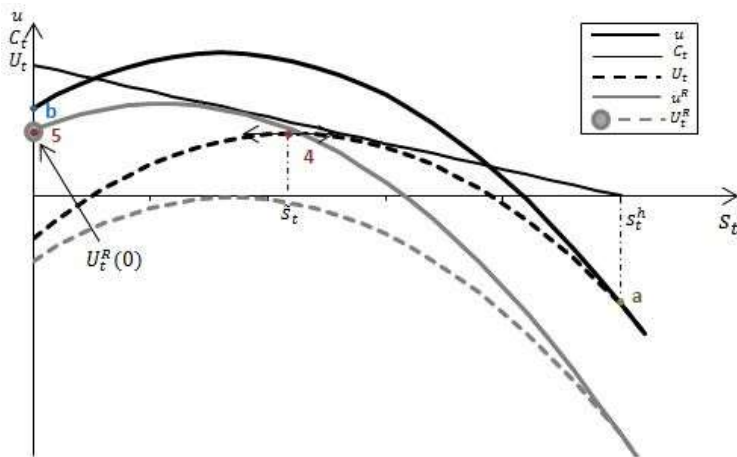
Finally, it is important to consider measures that tend to modify social norms. Unlike fear campaigns, such interventions let to the agent few margin for deny process. Indeed, individuals are concerned by social issues and the theory of reasoned action (Ajzen and Fishbein, 1980) postulate that one motor of the intention to act is based on subjective norms

that correspond to his beliefs about what people think that he should do or not. Some studies have illustrated this point by observing that smoking bans at work or in public places lead to smoking bans in private places, including homes (Cheng et al., 2011; Kairouz et al., 2014; Mons et al., 2012).

APPENDIX A. GRAPHS



(Fig.A.1.) Selection of avoidance strategy in the action stage. *Note:* in exposition lifestyle, total utility maximization provides the point 4 on Fig.A.1. The agent suffers long run regrets since the amount of welfare is smaller than what he would have received if he had never started addictive consumption (point b). By choosing avoidance strategy, utility function decreases (from u to u^A). However, adjustment cost function slope decreases (C_t function becomes C_t/m), and transforms the total utility function (U_t to U_t^A). The agent's optimal point corresponds to a smaller amount of addictive good, and to a greater welfare (point 5). It should be noted that if he enters into the hot mode, it will correspond to point a if in exposition, and to the point a' if in avoidance (the latter corresponds to lower welfare but the chances to suffer a' are smaller than the chances of getting a).



(Fig.A.2.) Selection of the rehabilitation strategy in the action stage. *Note:* Rehabilitation strategy permits the agent to move from point 4 to point 5 on Fig.A.2. Note that the higher the cost of rehabilitation, the greater the difference between the welfare that the individual would have received if he had never started consuming (point b), and the actual welfare experienced (point 5).

APPENDIX B. DEMONSTRATIONS

Demonstration B.1. $B(s_t, y_t)$ transformation into $B(s_t)$

$$B(s_t, y_t) = \alpha_s s_t + \alpha_{ss} s_t^2 / 2 + \alpha_y y_t + \alpha_{yy} y_t^2 / 2$$

where $\alpha_s, \alpha_y, \alpha_{ss}, \alpha_{yy}$ are the parameters with $\alpha_s, \alpha_y > 0$ and $\alpha_{ss}, \alpha_{yy} < 0$.

Budget constraint is $I = p_s s_t + p_y y_t$ (I, p_s and p_y are constant over time). Due to the relation $y_t = I/p_y - (p_s/p_y)s_t$, the benefit function can be transformed in order to obtain:

$$B(s_t) = \left[\alpha_s - \alpha_y \frac{p_s}{p_y} - \alpha_{yy} \frac{I_t p_s}{p_y p_y} \right] s_t + \left[\alpha_{ss} + \alpha_{yy} \left(\frac{p_s}{p_y} \right)^2 \right] s_t^2 / 2 + \left[\alpha_y \frac{I_t}{p_y} + \alpha_{yy} \left(\frac{I_t}{p_y} \right)^2 / 2 \right]$$

Condition: satiation level is beyond the consumer budget, so that $\alpha_s > -\alpha_{ss} \frac{I_t}{p_s}$ and $\alpha_y > -\alpha_{yy} \frac{I_t}{p_y}$.

Demonstration B.2. $B(s_t)$ shape

$$\frac{\partial B(s_t)}{\partial s_t} = \alpha_s - \alpha_y \frac{p_s}{p_y} - \alpha_{yy} \frac{I_t p_s}{p_y p_y} + \left[\alpha_{ss} + \alpha_{yy} \left(\frac{p_s}{p_y} \right)^2 \right] s_t \text{ with } \alpha_s - \alpha_y \frac{p_s}{p_y} - \alpha_{yy} \frac{I_t p_s}{p_y p_y} > 0 \text{ and } \left[\alpha_{ss} + \alpha_{yy} \left(\frac{p_s}{p_y} \right)^2 \right] s_t < 0.$$

Condition: $\alpha_s > \frac{p_s}{p_y} \left(\alpha_y + \alpha_{yy} \frac{I_t}{p_y} \right)$ preference for the addictive product must be important enough and the price ratio p_s/p_y must be sufficiently low.

The function $B_t(s_t)$ increases for $s_t < \frac{\alpha_s - \alpha_y \frac{p_s}{p_y} - \alpha_{yy} \frac{I_t p_s}{p_y p_y}}{\left[\alpha_{ss} + \alpha_{yy} \left(\frac{p_s}{p_y} \right)^2 \right]}$ and then decreases.

$$\frac{\partial^2 B(s_t)}{\partial s_t^2} = \left[\alpha_{ss} + \alpha_{yy} \left(\frac{p_s}{p_y} \right)^2 \right] < 0: \text{ the benefit function is represented by a bell shaped curve.}$$

Demonstration B.3. Avoidance strategy

Maximization of $U^A(s_t, S_t)$

The optimal addictive consumption point corresponds to the point where the slope of $C(s_t, S_t)/m$ equals the slope of $u^A(s_t)$. Since the slope of $u^A(s_t)$ equals the slope of $u(s_t)$, and the slope of $C(s_t, S_t)/m$ is smaller than the slope of $C(s_t, S_t)$, then the optimal amount of the addictive product will be smaller in avoidance strategy.

Optimal strategy

$$U^A(s_t, S_t) = B(s_t) - p_A - L(s_t) - C(s_t, S_t)/m = B(s_t) - L(s_t) - C(s_t, S_t) - \left(p_A + \frac{1-m}{m} C(s_t, S_t) \right) \text{ where } m > 1.$$

$$U^A(s_t, S_t) > U(s_t, S_t) \text{ if } \left(p_A + \frac{1-m}{m} C(s_t, S_t) \right) < 0 \Leftrightarrow C(s_t, S_t) > \frac{m}{m-1} p_A$$

i.e. when adjustment cost function is sufficiently low at the optimal consumption level, or when the cost of avoidance environmental cues p_A is low, or when adjustment cost are lowered enough, i.e. for large m ($\lim_{m \rightarrow +\infty} \frac{m}{m-1} = 1$).

Demonstration B.4. Rehabilitation strategy

$$B^R(0) = \alpha_y \frac{I_t - p_R}{p_y} + \alpha_{yy} \left(\frac{I_t - p_R}{p_y} \right)^2 / 2 = B(0) - \alpha_y \frac{p^R}{p_y} + \alpha_{yy} \left(\frac{-I_t p_R + p_R^2}{2p_y^2} \right)$$

$$B^R(0) = B(0) - \frac{p_R}{p_y} (\alpha_y + \alpha_{yy} \frac{I_t - p_R}{2p_y})$$

$\alpha_y + \alpha_{yy} y_t > 0$ whatever $y_t \leq \frac{I_t}{p_y}$ (the budget does not saturate demand).

Thus $\alpha_y + \alpha_{yy} \frac{I_t - p_R}{2p_y} > 0$ since $\frac{I_t - p_R}{2p_y} < \frac{I_t}{p_y}$

Thus $B^R(0) < B(0)$.

Demonstration B.5. Impact of an increase the addictive product price

$$\frac{\partial B(s_t)}{\partial p_s} = \left(-\alpha_y \frac{1}{p_y} - \alpha_{yy} \frac{I}{p_y^2} \right) s_t + \alpha_{yy} \frac{2p_s s_t^2}{p_y^2} \frac{1}{2}$$

$$\frac{\partial B(s_t)}{\partial p_s} = - \left(\alpha_y + \alpha_{yy} \frac{I}{p_y} \right) \frac{s_t}{p_y} + \alpha_{yy} \frac{p_s s_t^2}{p_y^2}$$

Since $\alpha_y y_t + \alpha_{yy} \frac{y_t^2}{2} > 0$ whatever $y_t \leq \frac{I_t}{p_y}$ (true because the budget does not saturate demand), the following relationship is deduced:

$$\alpha_y y_t + \alpha_{yy} y_t^2 > 0 \Leftrightarrow \alpha_y + \alpha_{yy} y_t > 0 \Leftrightarrow \alpha_y + \alpha_{yy} \frac{I}{p_y} > 0$$

In addition, $\alpha_{yy} \frac{2p_s + \Delta s}{p_y} < 0$ so that:

$$\frac{\partial B(s_t)}{\partial p_s} < 0.$$

Thus $B^s(s_t) < B(s_t)$, $\forall s_t > 0$ so an increase in the price of the addictive good has a negative effect on the budget. For an unchanged loss function and adjustment cost functions, the utility and total utility decrease, whatever $s_t > 0$. For $s_t = 0$, there is no modification since $B^s(0) =$

$$B(0) = \left[\alpha_y \frac{I_t}{p_y} + \alpha_{yy} \left(\frac{I_t}{p_y} \right)^2 / 2 \right].$$

$$\text{Moreover, } \frac{\partial^2 B(s_t)}{\partial s_t \partial p_s} = - \left(\alpha_y + \alpha_{yy} \frac{I}{p_y} \right) \frac{1}{p_y} + \left(\alpha_{ss} + \alpha_{yy} \frac{2}{p_y^2} \right) s_t < 0 \Leftrightarrow \frac{\partial B^s(s_t)}{\partial s_t} < \frac{\partial B(s_t)}{\partial s_t}.$$

An increase in price lowers the benefit function slope. Since the respective slopes of $L(s_t)$ and $C(s_t, S_t)$ are constant, this price increase also lowers the slopes of $u^s(s_t)$ and $U^s(s_t, S_t)$ comparatively to $u(s_t)$ and $U(s_t, S_t)$. Consequently, these functions ($B^s(s_t)$, $u^s(s_t)$ and $U^s(s_t, S_t)$) have a lower maximum for a lower amount of the addictive good.

$$\text{Furthermore, } \frac{\partial^3 B(s_t)}{\partial s_t^2 \partial p_s} = \alpha_{yy} \frac{2p_s}{p_y^2} < 0 \Leftrightarrow \frac{\partial^2 B^s(s_t)}{\partial s_t^2} < \frac{\partial^2 B(s_t)}{\partial s_t^2} < 0.$$

The bell shaped curve is preserved but the slope decreases quicker, and this intensifies the effects of a price increase when the amount of the addictive good increases.

Demonstration B.6. Impact of an increase of the loss function

Since L_t is assumed to be a linearly-increasing function, let $L(s_t) = as_t$ where a is the intensity of fear concerning the addictive good's negative effects.

$$u^L(s_t) = B(s_t) - L(s_t)$$

$$\frac{\partial u(s_t)}{\partial a} = -s_t < 0$$

Thus $u^L(s_t) < u(s_t) \forall s_t > 0$

An increase of fear lower the utility function whatever $s_t > 0$.

Moreover:

$$\frac{\partial^2 u(s_t)}{\partial s_t \partial a} = -1 \Leftrightarrow \frac{\partial u^L(s_t)}{\partial s_t} < \frac{\partial u(s_t)}{\partial s_t}.$$

This negative effect increases with the amount of the addictive good since the new utility function slope is smaller than the previous one, whatever $s_t > 0$.

However, utility function's bell shape is preserved since:

$$\frac{\partial^3 u(s_t)}{\partial s_t^2 \partial a} = 0 \Leftrightarrow \frac{\partial^2 u^L(s_t)}{\partial s_t^2} = \frac{\partial^2 u(s_t)}{\partial s_t^2}.$$

Demonstration B.7. Comparison of the avoidance strategy effects following an increase in the price of the addictive good or an increase of the loss function

In both cases, adoption of the avoidance strategy decreases utility function but not its slope:

$$u^{s,A}(s_t) < u^s(s_t) \text{ and } \frac{\partial u^{s,A}(s_t)}{\partial s_t} = \frac{\partial u^s(s_t)}{\partial s_t}, u^{L,A}(s_t) < u^s(s_t) \text{ and } \frac{\partial u^{L,A}(s_t)}{\partial s_t} = \frac{\partial u^L(s_t)}{\partial s_t}.$$

Thus, if $\frac{\partial u^s(s_t)}{\partial s_t}$ equalizes $\frac{\partial C(s_t, S_t)}{\partial s_t}$ for a lower s_t than $\frac{\partial u^L(s_t)}{\partial s_t}$, it also equalizes $\frac{\partial C(s_t, S_t)/m}{\partial s_t}$ for a lower s_t than $\frac{\partial u^L(s_t)}{\partial s_t}$.

Consequently, $\frac{\partial u^{s,A}(s_t)}{\partial s_t}$ equalizes $\frac{\partial C(s_t, S_t)/m}{\partial s_t}$ for a lower s_t value than $\frac{\partial u^{L,A}(s_t)}{\partial s_t}$.

The optimal amount of addictive good in the avoidance strategy is lower after an increase in its price, rather than after an increase of the loss function. However a lower amount induces a higher level of adjustment cost.

Demonstration B.8. The impact of an increase of the rehabilitation price p_R

When the agent opts for a rehabilitation strategy, he is sure to abstain from consuming the addictive good: $s_t = 0$. Thus, the remaining budget is spent on composite good.

$$B^R(0) = \alpha_y \left(\frac{I - p_R}{p_y} \right) + \alpha_{yy} \left(\frac{I - p_R}{p_y} \right)^2 / 2$$

$$\frac{\partial B^R(0)}{\partial p_R} = -\frac{\alpha_y}{p_R} - \alpha_{yy} \frac{I - p_R}{p_y^2} = -\frac{1}{p_y} (\alpha_y + \alpha_{yy} y_t) < 0$$

since $\alpha_y + \alpha_{yy} y_t > 0$ (the budget does not saturates demand).

Paying for rehabilitation causes a decrease in the utility perceived at $s_t = 0$, compared to the utility the individual would have received if he had never started smoking. The higher the rehabilitation price, the greater the benefits, so that utility is negatively impacted.

Moreover $\frac{\partial^2 B^R(0)}{(\partial p_R)^2} = \alpha_{yy} \frac{p_R}{p_y^2} < 0$, i.e. the higher the rehabilitation price, the less important the impact of a given price increase will be.

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